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Gough's Cave, Cheddar, Somerset: Microstratigraphy of the Late Pleistocene/ earliest Holocene sediments

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SYNOPSIS. Eleven thin sections of Late-glacial and early Holocene sediments from Gough's Cave were investigated by soil micromorphology in order to complement analyses of contemporary faunal and human remains. Despite the paucity of continuous vertical and lateral stratigraphic sequences, which were the result of cave exploitation during the first half of the twentieth century, we were able to elucidate site formation processes relating to both Late-Glacial environmental conditions and the burial environment affecting human remains.

INTRODUCTION

During 1987–1989 the Late Pleistocene (c. 12 ka bp) to earliest Holocene cave sediments at Gough's Cave, Cheddar, Somerset, were studied in conjunction with archaeological, human bone and faunal studies by R. Jacobi, A. Currant, and C. Stringer (Natural History Museum)(Jacobi, 1985, 1991; Currant *et al.*, 1989; Stringer, 1990, 2000; Currant, 1991). Sedimentological investigations, like the excavations, suffered from having only relict and fragmentary deposits to study, on account of the general removal of most of the cave fill during the opening up of the cavern during the first part of the twentieth century (Donovan, 1955). We therefore focused our attention upon extant sediment sequences dispersed within the upper part of the cave with Late Pleistocene deposits: i) Areas I and III of the North Wall of the cave, ii) the 'Skeleton Rift', iii) a cemented, early Holocene stalagmite on the 'South Wall', and iv) an earliest Holocene sequence in the 'Sand Hole'.

METHODS

Field

Undisturbed samples were collected during the excavations from North Wall Areas I (samples 44 and 59, G and H) and III (sample E), the 'Skeleton Rift' (sample D), cemented (Holocene) stalagmite on the 'South Wall' (sample F), and an earliest Holocene sequence in the 'Sand Hole' (samples A, B and C)(Table 1; Fig. 1). Samples were impregnated with an epoxy resin and manufactured into ~8 × 6 cm size thin sections at the Natural History Museum, London.

Eleven thin sections were made from Gough's Cave and were described according to Bullock *et al.* (1985) and Courty *et al.* (1989). They were viewed at a number of magnifications ranging from x1, up to x400 under a polarising microscope, employing plane polarised light (PPL), crossed polarised light (XPL), oblique incident light (OIL), and ultra-violet (blue) light (UVL) (cf. Stoops, 1996). The combined use of these different types of illumination permit a large number of identifications, such as apatite (bone, guano and coprolites) which autofluoresce under UVL. The authors also made use of comparative material of Pleistocene cave sediments (e.g., Courty *et al.*, 1989), including nearby Middle Pleistocene Westbury-sub-Mendip (Somerset) and Late Pleistocene King Arthur's Cave in the Wye Valley (ApSimon *et al.*, 1992; Macphail and Goldberg, 1999). In addition, the number of soil micromorphological investigations of palaeosols dating to the Dimlington Stadial, Windermere Interstadial and Loch Lomond Stadial has increased greatly since this original work was done at Gough's Cave. These include a number of chalky colluvial Allerød palaeosols (Rendzinas) from Kent (Macphail and Scaife 1987, Fig. 2.4; Preece *et al.*, 1995), a ranker from West Sussex (Macphail 1995) and a palaeosol formed in scree outside King Arthur's Cave (Macphail *et al.* 1999).

RESULTS AND INTERPRETATIONS

Soil micromorphological descriptions and findings are summarised in Table 1 and illustrated in Figs 1–7. In order to simplify presentation of the findings we have grouped the results and associated interpretations.

Pleistocene Deposits

Pleistocene deposits overlying the widespread, unfossiliferous, basal conglomerate are composed of gravels overlain by silt-rich sediments (Fig. 1) that represent an identifiable depositional/post-depositional sequence. We can broadly refine these characterisations as follows: 1) bedded silts, sands and gravels; 2) the formation of banded fabrics with associated link cappings; and 3) reworked and disrupted silts and sands; 4) minor biological reworking by roots and fauna, and 5) inwashing of silts and dusty clay.

Bedded silts (Fig. 2), sands and gravels (Fig. 4) are broadly related to an upward fining sequence associated with phreatic flow within the main chamber of the cave (cf. Gillieson, 1996, Fig. 5.3). These depositional episodes are tied to fluctuating/diminishing water flow events within the overall karstic system that give rise to a sequence of cobbles (e.g., the basal conglomerate; not sampled here), gravels (sample 59, Table 1), sand (samples G, H, D, E, I and 59), and mud (samples B and C). Very thick phreatic sands and gravels also typify the Middle Pleistocene basal fill at Westbury-sub-Mendip Cave (Macphail and Goldberg, 1999) and comparable karstic settings (e.g., Goldberg and Sherwood, 1994).

Fig. 1 Field photo of Gough's Cave, Area 3, lower red silts, sample I. Note faint traces of bedding next to the sampling box (8 × 6.5 cm); cf. Fig. 2.

At Gough's Cave, the basic sedimentary sequence has been modified by a number of post-depositional processes to produce different micro-sedimentary fabrics. For example, the banded fabrics/link capping features (Table 1) are the typical result of ice lensing produced by alternate freezing and thawing (Romans and Robertson, 1974; van Vliet-Lanöe, 1985, 1986). Extreme modification by freezing and thawing results in the fragmentation and chaotic mixing of the beds and link capping features, and infilling with impure clay and silt (Macphail, 1999) (Fig. 4).

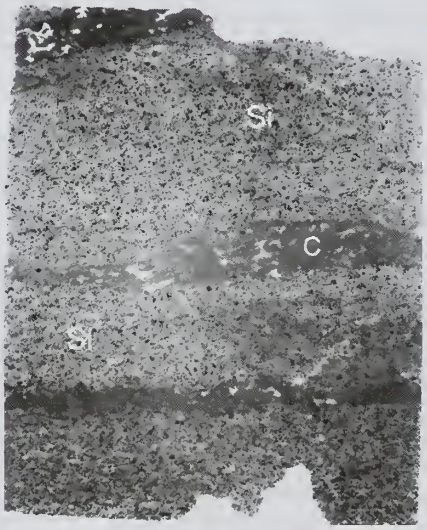

Fig. 2 Macrophotograph of whole thin section of sample I (cf. Fig. 1). Shown here are interbedded beds of elutriated silts (Si) and clay (C). Width of photo is 6.5 cm.

Biological activity is also recorded at Gough's Cave, forming channels and vughs through likely rooting and faunal burrowing. Finally, in this sequence many of these voids have been coated with dusty clay that implies renewed fluid transport vertically through the sediments (see below).

Sand Hole (Pleistocene to earliest Holocene)

Here the sequence commences with the deposition of cave muds (sample C) that accumulated in the base of the Sand Hole. These muds are composed of clay with clasts of redeposited clay (Fig. 5) and accumulated under conditions of low energy ponding. These deposits have reticulate b-fabrics induced by minor shrinking and swelling that reflect alternating periods of wetting and drying. It is possible that these muds are the finest deposits within the cave system, recording the end member of the upward fining sequence present in the main chamber. It is likely that this red clay owes its ultimate origin to the weathering of the Carboniferous Limestone, and is a form of transported ßeta B clay (Duchaufour, 1977).

In the Sand Hole, the sequence continues with the 'Laminated Stalagmite' and the 'Frog Earth' (Figs 6, 7). The laminated stalagmite is composed of cryoclastically produced fallen limestone clasts and clay beds, which are both partially cemented by micrite originating from drip. These deposits are succeeded by muds containing large numbers of frog bones that appear to be typical of early Holocene faunas (Currant, NHM, pers. comm.).

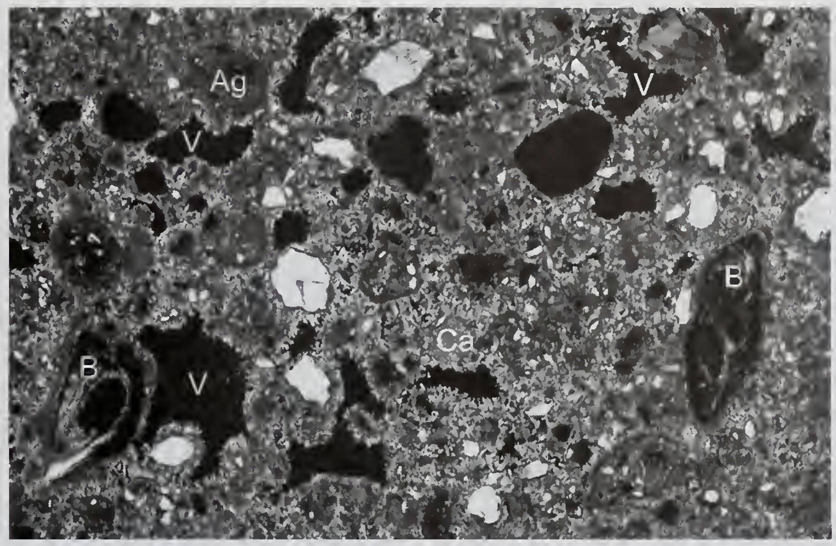

Fig. 3 Gough's Sample D (Table 1), consisting of rounded bone (B) and clayey sediment aggregates (Ag) in a calcareous silty clay. Note secondary porosity (V) composed of channels and vughs that feature secondary calcite carbonate growth. XPL; width of photo is ca. 5.4 mm.

DISCUSSION

It has not been an easy task to reconstruct the sedimentary history of Gough's Cave, because the micro-sedimentary evidence by necessity, has been gathered from the small (max. 40 mm thick) pockets of sediment that remain on the extreme edges of the main cave, and the mainly early Holocene sequence in the Sand Hole.

The sequence at Gough's is quite localized and built up from non-continuous exposures within the cave, and so must be considered as yielding only a partial history of the cave. The sedimentary sequence commences with the deposition of the conglomerate, followed by sands and gravels that fine upwards to the red silts, with muds being restricted only to the Sand Hole (Table 1). This Late Glacial accumulation lasted from about 12,000 to 10,500 ^{14}C years bp, and seems to be roughly correlated with the Windermere Interstadial (ca. 13,000 to 11,000 ^{14}C years bp) through to the Loch Lomond Stadial (11,000 to 10,000 ^{14}C years bp). Human skeletal remains occurred within the red silts and were variably coated with silty clay through to sand and fine gravel (Currant and Stringer, NHM, pers. comm.). The bones (Stringer, 2000) that date to ca. 13,000 to 11,500 radiocarbon years ago would thus appear to be *in situ* and contemporary with the lower energy deposition of the upward fining sequence.

This phreatic period appears to be contemporary with both Upper Palaeolithic activity and the Windermere Interstadial (Table 2). The formation of the conglomerate can perhaps be best related to

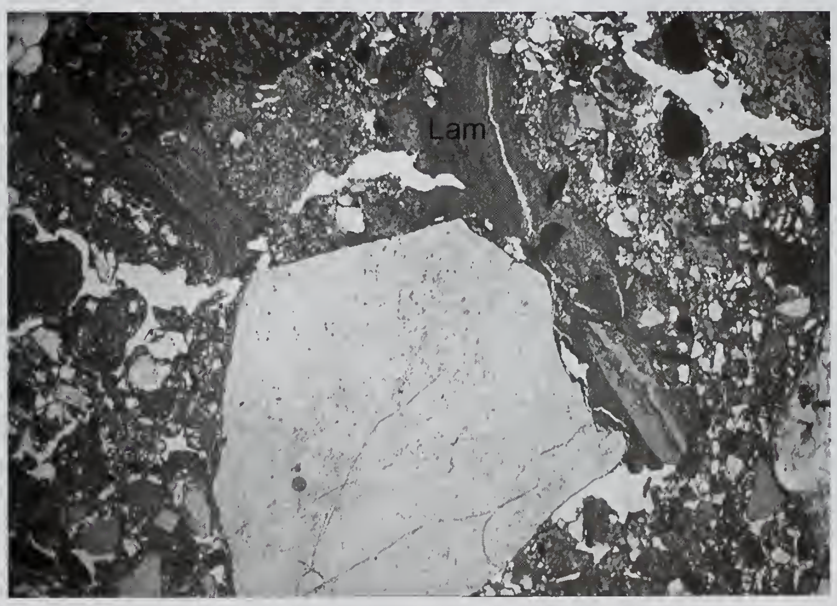

Fig. 4 Sample B from Gough's Cave (Table 1). Macroview of laminated silts and clays over conglomerate, the basal deposit. Width of photo ca. 1.1 cm.

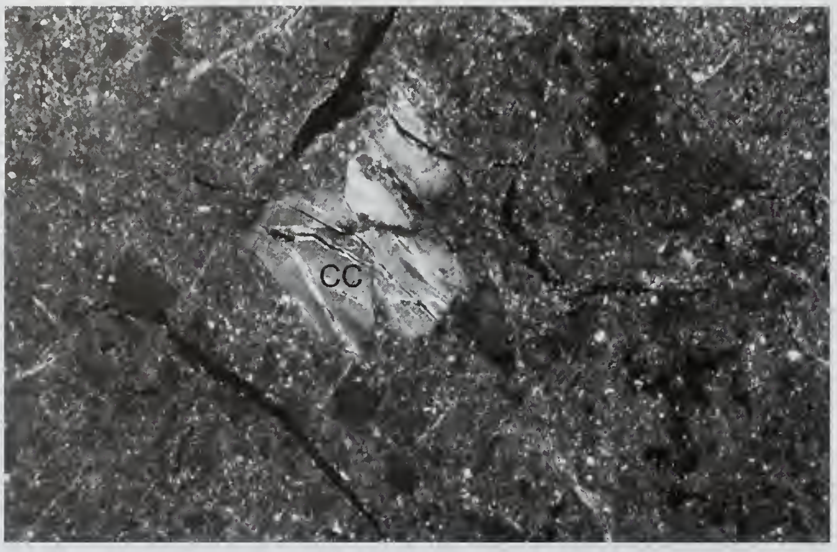

Fig. 5 Sample C from the sand hole, a basal clay deposit including a locally reworked clay (CC). Note the reticulate birefringent fabric which is indicative of minor shrinking and swelling reflecting alternate periods of wetting and drying. Width of photo ca. 5.4 mm.

cryoclastic activity and high energy phreatic flow occurring near the last glacial maximum. It is likely that diminishing phreatic flow and the upward fining sedimentary sequences situated at the sampled margins of the cave, occurred from the end of the Devensian (Oldest Dryas) to the Windermere Interstadial (Bølling/Allerød). This interval was contemporary with Upper Palaeolithic activity that led to the deposition of human skeletal remains in sediments that were once well-bedded (Fig. 2). It seems likely that the ice lensing activity noted in sample H, could be related to occasional cold conditions continuing into the Interstadial. The presence of humans is totally unrecorded at this period in the samples from Areas I and III and the Skeleton Rift, but a breccia remnant ('reindeer stalagmite') from the just below the cave roof does include some charcoal, as seen in thin section.

The mild conditions of the Windermere Interstadial are best recorded, albeit weakly, by biological activity producing an enhanced porosity pattern of channels and vughs (e.g., in samples 44 and D; Fig. 3). Other contemporary sites in southern England have produced longer sedimentary sequences. For example, a number of chalky colluvial deposits have been described from Kent and the Isle of Wight (e.g. Preece *et al.*, 1995). These are soil-sediments, with biological activity and pedogenesis being recorded through slightly enhanced amounts of organic matter, and in places, by concentrations of earthworm granules that indicate ephemeral land surfaces (Preece *et al.*, 1995). At King Arthur's Cave, Herefordshire, a very thin and weakly humic soil horizon was identified through soil micromorphology and chemistry (Macphail *et al.*, 1999). This soil

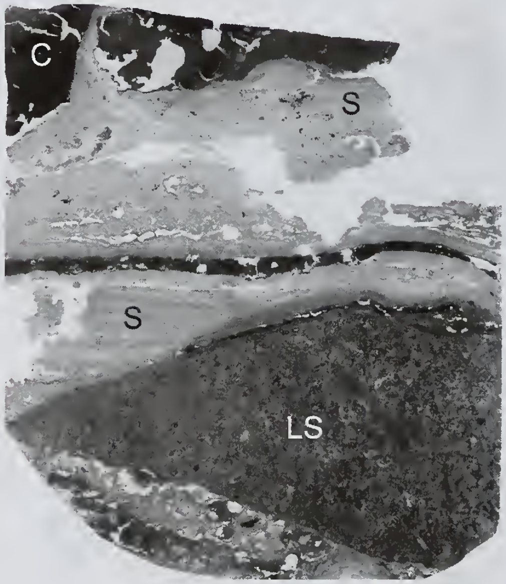

Fig. 6 Sample A3 composed of laminated stalagmite (S) overlying fallen limestone clast (LS) with stringers of red clay (C). Width of photo is ca. 4 cm.

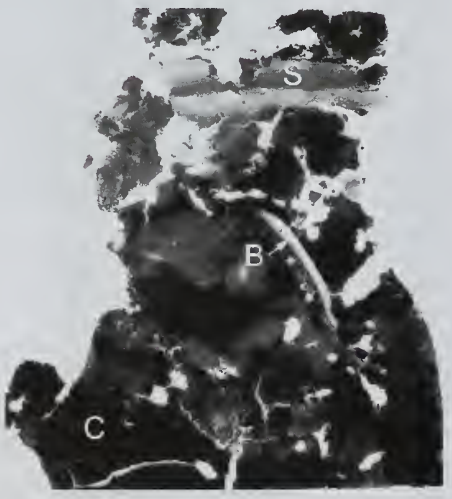

Fig. 7 Sample A (Frog Earth) in sand hole showing clay beds (C) with included bone (B) capped by an iron-stained stalagmite deposit (S). Width of photo is ca. 4 cm.

had formed in Late Devensian scree produced from limestone, and was itself sealed by further scree dating to the ensuing Loch Lomond Stadial. Thus the dominance of sedimentation over 'pedogenic' and post-depositional effects, as at Gough's Cave is typical of Windermere Interstadial sites. One exception is the interstadial soil at Westhampnett, West Sussex, where a very thin *in situ* humic ranker had formed under a likely coniferous woodland cover (Macphail, 1995).

At Gough's Cave the renewed cold conditions of the Windermere Stadial are apparently recorded in the major disruption of sedimentary bedding and previously formed banded fabrics/linked cappings. This cold climate produced chaotic mixing of the deposits and resulted in the infilling of void space with impure clay and silts and clays (Figs 3, 4). Some channels and vughs formed previously by biological activity are coated and infilled, clearly revealing that the period of inwashing post-dated this activity (Table 2). Some of the clayey sediment adhering to the skeletal remains could thus be of the same origin, the orientation of the bones also possibly reflecting this period of disruption. For example, in the well-preserved Upper Palaeolithic occupation cave deposits at Arene Candide, Liguria, Italy, once- horizontal hearths were disrupted by this (Younger Dryas) freezing and thawing (Macphail *et al.*, 1994).

At the Sand Hole, the lowermost clay deposits (Fig. 5) appear to have been little affected by the Loch Lomond Stadial, but rather seem to reflect sedimentation strongly associated with faunal activity during the Late Pleistocene-Early Holocene transition. Typical of earliest Holocene deposits, speleothem formation dominated sedimentation in the Sand Hole, with the moist conditions possibly also favouring the contemporary amphibian fauna (Currant, NHM, pers. comm.).

CONCLUSIONS

This study of the sediment micromorphology enabled us to identify the sedimentary sequence that was contemporaneous with the human occupation/Windermere Interstadial, in spite of the paucity of a continuous sequence of cave sediments. Specifically, we were able to demonstrate an upward fining sedimentary sequence, pene-contemporary with both cool and mild climatic effects. The last led to ephemeral biological activity, and is consistent with a number of other contemporary, sediment-dominated sites in southern England. The investigation also showed that not only sediments but also the skeletal remains themselves were likely influenced by localised post-depositional processes (minor reworking, fine sediment inwash), dating to the cooler conditions of the Loch Lomond Stadial (?). In the Sand Hole, the transition between the Windermere Interstadial/Loch Lomond Stadial and the earliest Holocene, is recorded in the sediments. This detailed microstratigraphic approach exemplified here appears to offer the ability to extract the maximum sedimentary information from disparate and discontinuous deposits within a sedimentary system.

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Table 1 Selected soil micromorphological observations.

Area/Context/ Unit	Sample	Relative Depth (m)	Field	Micromorphology
'Sand Hole'				
'Frog earth'	A upper	-	0-0.19 m: Yellowish red (5YR4/6) sandy loam.	*Structure*: Massive, intermixed coarse silts and fine sand with thin beds and very coarse infills of silty clay; coarse vughy porosity. Very abundant sand-size bone, coprolite and possible fish bones; occasional long (3 cm) amphibian? bones; vertebra? also present; inclusions of stalagmite. Microfabric: C:F, 80:20, speckled brown (PPL), medium to high interference colours (close porphyric, crystallitic b-fabric; XPL), orange brown (OIL); rare charcoal.
'Laminated stalagmite'	A lower	0.11-0.27	0.19-0.41 m: pink (5YR7/4) laminated stalagmite.	*Structure*: Very finely (200 µm) bedded stalagmite with coarse limestone inclusions and silty clay bands. Likely lichen/algal stalagmite growth. Lower part contains few very leached bone fragments, otherwise sterile. Microfabric: whitish to cloudy grey (PPL), high to very high interference colours (crystallitic b-fabric); white to greyish brown (OIL); very abundant pseudomorphs of plant material in places. Porous basal stony layer features abundant micritic (with clay staining) coatings.
'Brown Clay'	B	0.42-0.47	0.41-0.49 m: reddish brown (5YR5/4) clay, with whitish patches (bone ghosts?); clay mixed with stalagmite and blackened, possible reindeer bones.	Lower part of this massive and heterogeneous clay is sterile except for rare plant fragments, while the upper part is rich in very fine to coarse sand-size, very pale bone, with 'vole' teeth. Under UVL, the bone has a whitish grey autofluorescence; pores within the bone are also infilled with dirty clay. The sediment is also characterised by a patchy autofluorescence under UVL, and a partially closed vughy porosity. Microfabric: C:F. 80:20; dominant (clast supported) angular small stone size limestone and calcite, common angular to subrounded fine to medium sand and silt-size quartz; speckled brown and greyish brown (PPL), moderate to high interference colours (close porphyric, crystallitic b-fabric; XPL), bright orange brown (OIL); frequent (15%) coarse packing voids, with many clayey/calcitic coatings in the lower part and many dark red clay coatings in upper part.
'Red Clay'	C; 2 thin sections	0.50-0.66	0.49-0.90+ m: yellowish red (5YR4/6) 'sterile'? clay over limestone blocks.	*Structure*: Dense massive, with rare interconnecting channels, fine bone and occasional plant fragments and possible *in situ* roots. At the base, cracks are present alongside rare plant fragments and many sand-size red clay papules (Fig. 2); C:F, 20:80; silt-size quartz, and rare very fine sand; speckled dark yellow/reddish brown (PPL), low interference colours (open porphyric, reticulate b-fabric; XPL), orange brown (OIL).
South Wall				
'Reindeer stalagmite'	F; 2 thin sections	-	Post stalagmite brown silt and charcoal, over stalagmite containing a reindeer tooth and charcoal.	*Structure*: Massive with disrupted beds and many closed vughs. Poorly sorted with stone size, angular limestone and sand-size quartz; charcoal, many bones and occasional teeth; C:F, 60:40; common to dominant stone inclusions (some limestone showing etching), with frequent to common medium sand of quartz and flint, with very few fine sand size to gravel size bone – some brown stained some leached and rounded (ex-regurgitation pellets?), possible teeth fragments; occasional sand size rounded charcoal; patchy grey and brown (PPL), medium and high interference colours (gefuric and open porphyric, crystallitic b-fabric, XPL), grey and pale brown (OIL); many 1-8 mm thick silty clay pans (width of slide); abundant brown clayey micritic hypocoatings on voids and embedding large clasts.
North Wall				
Area 1 (1987)				
Red Silt	44	0-0.15	Red Silt.	*Structure*: Massive to weakly coarse platy; *Porosity*: lower 20 mm ~5% voids, with fine channels and vughs; uppermost 25 mm 15-20% voids of coarse, smooth-walled vughs and channels. *Mineral*: C:F, 85:15 in lower 20 mm with horizontal fine (200 µm) bands of 100:00 (elutriated) very dominant silt to fine sand size angular quartz (and mica); with frequent fine, medium and coarse sand size quartz, limestone (also calcite); poorly rounded fragments of clay pans, clay/soil granules, sediment papules. Top 25 mm: dominant very coarse sand size quartz, quartzite, ferruginous nodules, etched calcite

continued ...

Table 1 *continued*

				clay/soil granules, sediment papules. Top 25 mm: dominant very coarse sand size quartz, quartzite, ferruginous nodules, etched calcite and weathered limestone. Inclusions of silt size pale yellowish autofluorescent material (UVL) representing reworked phosphatic coprolitic material. Fine mineral is composed of very dominant pale brown, dotted (PPL), low interference colours (close porphyric speckled b-fabric, XPL), pale orange brown (OIL). Very little organic matter. *Pedofeatures*: very abundant textural pedofeatures. Lower 20 mm: very abundant intercalations, occasional very dusty clay void coatings; in upper 25 mm very abundant, very dusty/impure clay void coatings; coatings on all void surfaces and ped faces; fabric pedofeatures composed of abundant inclusions of banded dusty clay/link capping material as fragments.
Gravels over conglomerate	59	-	Gravels.	*Structure*: massive. *Porosity*: 10-20% voids generally coarse channels and vughs. *Mineral*: C:F, 85:15 (silts) to 95:5 (gravels). Common gravel to very coarse sand size limestone (subangular to angular): various rounded/weathered aragonite, with flint/chert, siltstone, etc. Common silt size and fine sand size quartz with very few mica. Fine material composed of pale brown, speckled (PPL), low interference colors (close porphyric, speckled b-fabric, XPL), pale brown orange (OIL). No obvious organic matter. *Pedofeatures*: very abundant intercalations, dusty/impure clay void coatings, pans, 'micro-channel infills'. Very abundant banded fabric of clean silts.
Area 1 (L.102 metre square)				
Red Silt	G	0-0.095	Red silt beneath cave roof.	As Sample 44. Massive, very fine and coarse banded material with lamina fabric; generally closed vughs. An upward fining sequence of coarse silt to fine silty and clay. Contains rare plant fragments as well as phosphate clasts.
Red Silt	H	0.33-0.40	Red silt beneath cave roof, over conglomerate.	As Sample 44. Massive/fine banded, composed of strongly elutriated coarse silts with few mixed in coarse clayey fragments and sand size material. Top of sample contains a gravel and silt band.
Skeleton Rift				
Red Silt	D	0-0.17	0-0.05 m: Red silt beneath cave roof. 0.05+ m: Conglomerate.	As Samples 44 and 59. Massive with coarse banded silts. Upwards, deposit is composed of gravel-rich silts with stone-sized angular to subangular limestone clasts. Deposit is poorly sorted, mainly silt size material, with common sand, strongly disrupted banded fabric of dusty clay and silt pans with included sand. Inclusions of likely fragmented link cappings as sand size clasts; rounded bone present.
Area 3				
Red Silt	E	0-0.16	0-0.16 m: Red silt beneath cave roof (concrete floor) over conglomerate.	As Sample 44. Breccia; massive with few vughs and fine channels. Highly compact sediment; weakly to moderately impregnated with calcium carbonate; poorly sorted mixture of stone size, subangular limestone and a matrix of dominantly silt size quartz, mica and calcite. Also includes coarse sand size quartz, weathered limestone, fossils and speleothem. Patchy iron staining and depletion; possible occasional charcoal stuck to the roof. Few included, embedded/coated grains. Occasional thin to thick, very dusty to impure coatings.
Red Silt	I	0-0.16	0-0.16 m: Red silt beneath cave roof (concrete floor) over conglomerate.	Massively banded silts and clays with repeated graded beds. Some fine channeling at the top. Most of porosity in the form of packing voids.

Table 2 Tentative summary of sedimentary activity in Gough's Cave as reconstructed from soil micromorhpology.

Age (^{14}C yrs bp x 1000)	Period	Deposition	Post-Deposition	Comments
9				
10	Early Holocene	Formation of stalagmite and frog bone-rich muds in the Sand Hole	Stalagmite formation.	Climatic amelioration associated with warm and moist conditions (cf. frogs).
11-10	Loch Lomond Stadial (Younger Dryas)	Accumulation of breccia sediments in Sand Hole	Patchy formation of banded fabric and link capping, accompanied in places by physical mixing. Washing of impure clay into voids.	Renewal of cold conditions leading to freezing and thawing associated with increased meltwater activity.
13 to 11	Windermere Interstadial (Bolling/Allerød)	Upward fining sequence from gravels and sands through to the Red Silt; deposition of mud in the Sand Hole	Ephemeral biological activity producing channels and vughs. Localized ice lensing in the lowermost Red Silt.	Increased moderation in climate. Diminishing phreatic flow, possibly accompanied by ice-lensing in the early stages
16 to 13	Devensian (Oldest Dryas)	Formation of Conglomerate		Cryoclastic activity accompanied by high energy phreatic flow.